Constellation Design for a Mars-Orbiting Satellite Communication and Navigation Network

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Extended Abstract

As part of NASA's effort to support Mars exploration, constellation design work has been done for a network of small satellites that will provide communication relay and navigation support for a variety of future Mars missions, both robotic and piloted. The key objectives of this constellation are to provide increased data return, enable autonomous onboard navigation without relying on Earth-based tracking data, and substantially lower the combined operations costs anticipated for Mars exploration.

In the present design, each satellite in this constellation would be launched as secondary payloads on an Ariane 5, with one or two sent to Mars every 26 months (Figure 1). These satellites will be 3-axis stabilized, solar powered, and will carry a UHF transceiver package integrating communication and navigation functions for landers, rovers, penetrators, airborne vehicles, and orbiters. An X-band telecommunication system will be used to transmit collected engineering, science and navigation data back to Earth.

The first lander of the Mars Sample Return Mission will land near the equator; we anticipate that coverage around lower latitudes (+/-20°) is of initial importance. This decision dictates at least one equatorial orbiter to support this mission. Later on, more global coverage will be provided by a combination of middle and high inclination orbits. The issue of orbit size is complicated, because communication requirements strongly favor lower altitude orbits (400 to 600 km), yet good position fix geometry is provided by satellites in higher altitude orbits. The current working model of this constellation is composed of six satellites in 600 km altitude circular orbits at inclinations of 10°, 50° and 79°.

This paper presents the results of system analyses and trade studies on different constellations designs. The analysis is guided by anticipated requirements, candidate Mars missions scenarios, and the desire to supply a evolving, enabling capability for future unspecified missions. The performance of the candidate constellation designs will be illustrated using navigation and communication metrics developed for this design task, which allow quick comparisons between design options. These metrics are compared with a variety of requirements derived from representative "user" missions, including a stationary lander and an orbiting sample canister. From these initial studies the best constellation design will be chosen for more detailed study using higher-fidelity models. In addition to describing the methodology and results of this task, this paper will discuss possible tradeoffs, constraints imposed by specific missions that this constellation will serve, and other open issues.

[A companion paper, entitled "Architectural Design for a Mars Communication and Navigation Orbital Infrastructure" will provides a high-level overview of the concept of the Mars communication and navigation infrastructure, mission requirements, and considerations for launch and Mars delivery.]

FIGURE 1: **Mars NavComm Infrastructure Evolution**